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Changes in Carabidae assemblages of municipal parks caused by environment factors

Abstract: The beetle family Carabidae inhabits natural and anthropogenically transformed habitats. Due to their widespread occurrence and our good knowledge of their biology, carabid beetles are very suitable zooindicators. Analyses of ground beetle communities can help to evaluate the condition of typical urban habitats. The present study, carried out in 2011 in three parks in the town of Olsztyn (UTM: DE 65), revealed differences in the species composition of Carabidae communities dwelling in tree assemblages, as well as in the numbers of individuals and species. An attempt was made to identify the most important habitat characteristics which affected the structure of carabid communities. A distinct differentiation depending on the plant cover in the analyzed habitats and the moisture content was observed. Also, a significant impact of anthropopressure on these valuable and ecologically highly flexible insects was confirmed.

Key words: ground beetles, anthropopressure, municipal parks

Introduction

Urbanized areas are very specific ecosystems inhabited not only by people but also by a high number of species of plants and animals. Such areas are characterized by a very strong spatial differentiation of microhabitats. Another distinguishing feature is the exposure to various pollutants and possible interference with proper functions of these specific ecosystems (Mc Intyre *et al.* 2001, Angold *et al.* 2006). Urbanization causes extensive changes in the natural environment often resulting in the disapppearance of many plant and animal species (Elek & Lövei 2007). Current requirements resulting from an urban planning concept that takes into account ecological aspects of urbanization state that – apart from utalitarian functions – urban development designs should contain provisions to protect valuable plant communities and preserve biodiversity (Niemela 1999). Animals are often used as an indicator of biodiversity when assessing habitats (Mc Geoch 1998). Among the most thoroughly recognized zooindicators are epigeic carabid beetles (Coleoptera; Carabidae) due to their high sensitivity to environmental conditions. This group responds to various changes in the surroundings, including those caused by urbanization (Czechowski 1982). Other advantages of carabid beetles as zooindicators are their diversity, widespread occurrence and our relatively good knowedge of their ecology (Niemela *et al*. 2000; Szyszko 2002; Skłodowski 2002, Rainio & Niemela 2003). Towns and cities, although examples of environments completely transformed by humans, are characterized by quite a high heterogeneity, with numerous habitats acting as pools of biological diversity. These are mainly all types of tree assemblages, shrubs, parks, tree-lined streets and paths, cemeteries, and others, all an invariable component of towns and cities. Analyses of carabid communities may help to evaluate the condition of plant communities typical of urban surroundings.

The purpose of this study was to determine the abundance and species composition of epigeic ground beetles dwelling in municipal tree communities differing in the composition of trees, soil cover by herbaceous plants, presence or absence of a shrub layer, humidity as well as by the degree of anthropogenic pressure caused by frequent and numerous visits of people. Also an attempt was made to determine which of these factors had the strongest effect on the structure of the carabid communities.

Study area and methods

The study was conducted within the administrative borders of the city of Olsztyn (UTM: DE 65), north-eastern Poland. Carabidae were captured in three different tree assemblages. Site A was a community of trees near a housing estate, crisscrossed with footpaths and under the strongest anthropopressure of all investigated sites. Tree species were mainly Pine *Pinus silvestris*, which made up about 80% of all trees, and deciduous species like Birch *Betula veruscosa* and Maple *Acer platanoides* all of which were about 70-80 years old. There was a rich layer of shrubs, and up to 70 % of the soil surface was covered with herbaceous plants. This site also had the lowest soil moisture. Site B was located about 400 m from a lake, with a tree community on quite wet substrate. Tree species were mostly Beeche *Fagus sylvatica* and Hornbean *Carpinus betulus*, about 90 years old. This tree community had a very poor layer of shrubs and a small (40%) cover of herbage. Site C comprised trees growing right next to a lake in a park. The underlying soil had the highest moisture of all sites. Deciduous 50- to 60-year-old trees such as Poplar *Populus alba*, Maple *Acer platanoides*, Willow *Salix cinerea*, ans Aspen *Populus tremula* dominated. The shrub layer was only slightly poorer than in site A, while the soil cover with herbaceous plants was the highest. The location of the three investigated tree communities and their immediate surroundings (houses, avenues, footpaths) results in the ranking A > B > C with increasing influence of anthropogenic factors.

Specimens of Carabidae were captured in modified Barber traps set up in mid-May and kept until the end of October 2011. They were emptied every two weeks. In each type of a tree community, three transects were set at least 100 m apart from each other. Each individual transect consisted of four traps in a straight line and 10 m from each other. Collected beetles were identified on the level of species following Hůrka (1996). The diversity of the Carabidae communities was assessed with the Shannon-Weaver index (H' log base 2,718), Pielou index of evenness (J') and Simpson index of species richness (D). The significance of differences between the mean values of these indices and the abundance and number of species was assessed wit a one-factorial analysis of variance ANOVA. A Canonical Correspondence Analysis (CCA) was applied to arrange the data and demonstrate relationships between the caught

Carabidae species and the habitat-specific features moisture content of habitat substrate; soil cover with herbaceous plants, presence of shrubs, presence of conifers, presence of deciduous trees; distance to lake, and anthropogenic pressure. In figure 3 the analyzed sites and the occurrence of Carabidae species are arranged relative to the two main axes of differentiation.

Statistical significance of the canonical axes was determined with the Monte-Carlo test. All statistical calculations and graphics were done with Statistica 11 PL and Canoco v.4.56 (Ter Braak & Milauer 1998).

Results

In total, 1,581 specimens from 49 Carabidae species were collected (tab. 1). The three study sites differed significantlyin the number of individuals ($F = 14.87$; $p < 0.01$) as well as of species ($F = 14.20$; $p < 0.01$), (tab. 2). The lowest number of ground beetles (241 individuals) was noted in site A which was under the strongest anthropogenic pressure (fig. 1). In contrast, 734 specimens were caught at site B and 606 at site C (tab. 1). However, site A was characterized by the highest number of captured species (35), differing significantly from sites B (18) and C (25) (fig. 2). A similar result was obtained for species diversity and evenness, with the respective values H' (2.80) and J' (0.79) again highest for site A (tab. 2). The Simpson index, however, also known as the index of dominance concentration, was highest for site B, characterized by the largest number of captured individuals and a small number of species.

Table 1. Species composition, number of individuals (n) and dominance [%] among Carabidae in the analyzed urban parks

Species	Study area					
	A		B		C	
	n	%	n	%	n	%
Nebria brevicollis (Fabricius, 1792)	60	24,90	546	74,39	208	34,32
Limodromus assimilis (Paykull, 1790)	10	4,15	96	13,08	38	6,27
Patrobus atrorufus (Strom, 1768)	6	2,49	6	0,82	117	19,31
Pterostichus anthracinus (Illiger, 1798)	5	2,07	10	1,36	96	15,84
Loricera pilicornis (Fabricius, 1775)	17	7,05	16	2,18	36	5,94
Pterostichus melanarius Illiger, 1798	9	3,73	6	0,82	39	6,44
Pterostichus nigrita (Paykull, 1790)	3	1,24	1	0,14	23	3,80
Amara convexior (Stephens, 1828)	19	7,88	0	0	7	1,16
Calathus fuscipes (Goeze, 1777)	26	10,79	0	0	0	0
Amara communis (Panzer, 1797)	16	6,64	0	0	9	1,49
Leistus rufomarginatus (Duftschmid, 1812)	2	0,83	17	2,32	2	0,33
Epaphius secalis (Paykull, 1790)	0	0	19	2,59	0	0
Amara ovata (Fabricius, 1792)	14	5,81	0	0	1	0,17
Notiophilus palustris (Duftschmid, 1812)	11	4,56	0	0	0	0
Anchomenus dorsalis (Pontoppidan, 1763)	0	0	3	0,41	3	0,50
Anisodactylus binotatus (Fabricius, 1787)	0	0	0	0	6	0,99
Calathus erratus (Sahlberg, 1827)	6	2,49	0	0	0	0

Bembidion guttula (Fabricius, 1792)	1	0,41	4	0,54	0	0
Harpalus tardus (Panzer, 1797)	5	2,07	0	0	0	0
Notiophilus biguttatus (Fabricius, 1779)	4	1,66	1	0,14	0	0
Oodes helopioides (Fabricius, 1792)	0	0	0	0	5	0,83
Bembidion mannerheimii (C. Sahlberg, 1827)	0	0	4	0,54	0	0
Harpalus xanthopus winkleri Schauberger, 1923	4	1,66	0	0	0	0
Agonum fuliginosum (Panzer, 1809)	0	0	0	0	3	0,50
Amara bifrons (Gyllenhal, 1810)	3	1,24	0	0	0	0
Bembidion lampros (Herbst, 1784)	2	0,83	0	0	1	0,17
Clivina collaris (Herbst, 1784)	0	0	0	0	3	0,50
Harpalus rufipes (Degeer, 1774)	2	0,83	1	0,14	0	0
Pterostichus minor (Gyllenhal, 1827)	1	0,41	1	0,14	1	0,17
Pterostichus strenuus (Panzer, 1797)	3	1,24	0	0	0	0
Harpalus latus (Linnaeus, 1758)	1	0,41	0	0	1	0,17
Ophonus rufibarbis (Fabricius, 1792)	1	0,41	0	0	1	0,17
Oxypselaphus obscurus (Herbst, 1784)	0	0	0	0	2	0,33
Stomis pumicatus (Panzer, 1796)	0	0	1	0,14	1	0,17
Amara tibialis (Paykull, 1798)	1	0,41	0	0	0	0
Asaphidion flavipes (Linnaeus, 1761)	1	0,41	0	0	0	0
Badister bullatus (Schrank, 1798)	1	0,41	0	0	0	0
Badister lacertosus Sturm, 1815	1	0,41	0	0	0	0
Badister meridionalis Puel, 1925	0	0	1	0,14	0	0
Bembidion femoratum Sturm, 1825	0	0	0	0	1	0,17
Calathus melanocephalus (Linnaeus, 1758)	1	0,41	0	0	0	0
Carabus granulatus Linnaeus, 1758	1	0,41	0	0	0	0
Curtonotus aulicus (Panzer, 1797)	0	0	0	0	1	0,17
Dyschiriodes globosus Herbst, 1784	1	0,41	0	0	0	0
Harpalus affinis (Schrank, 1781)	0	0	1	0,14	0	0
Poecilus lepidus (Leske, 1785)	1	0,41	0	0	0	0
Pterostichus niger (Schaller, 1783)	0	0	0	0	1	0,17
Pterostichus oblongopunctatus (Fabricius, 1787)	1	0,41	0	0	0	0
Synuchus vivalis (Illiger, 1798)	1	0,41	0	0	0	0
Number of individuals	241	100,00	734	100,00	606	100,00
Number od species	35		18		25	

Table 2. Mean number (± SE) of individuals and species per trap and indices describing the assemblage of Carabidae at the study areas A, B and C. a, b – homogenous groups (Duncan's test)

Indices	Study areas		
	A	B	C
Shannon H' (log Base 2.718)	2.80	1.03	2.03
Pielou J'	0.79	0.36	0.63
Simpson D	0.01	0.57	0.19
Mean number of individuals	1.83 ± 0.20a	5.52 ± 0.66b	4.59 ± 0.52b
	F = 14.87, p < 0.01		
Mean number of species	1.2 ± 0.12a	1.41 ± 0.08a	2.05 ± 0.14b
	F = 14.20, p < 0.01		

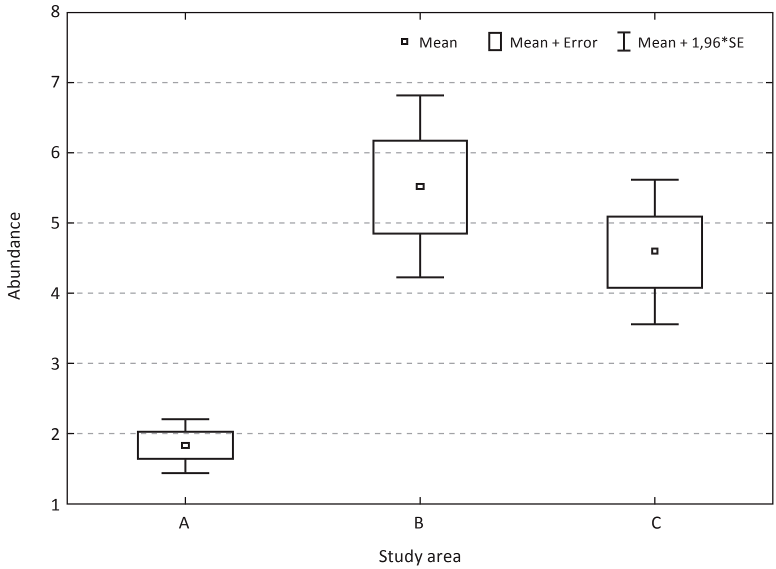

Figure 1. Mean number of individuals (per trap) of Carabidae populating three urban forests (A, B, and C). Significance is indicated at p < 0,05

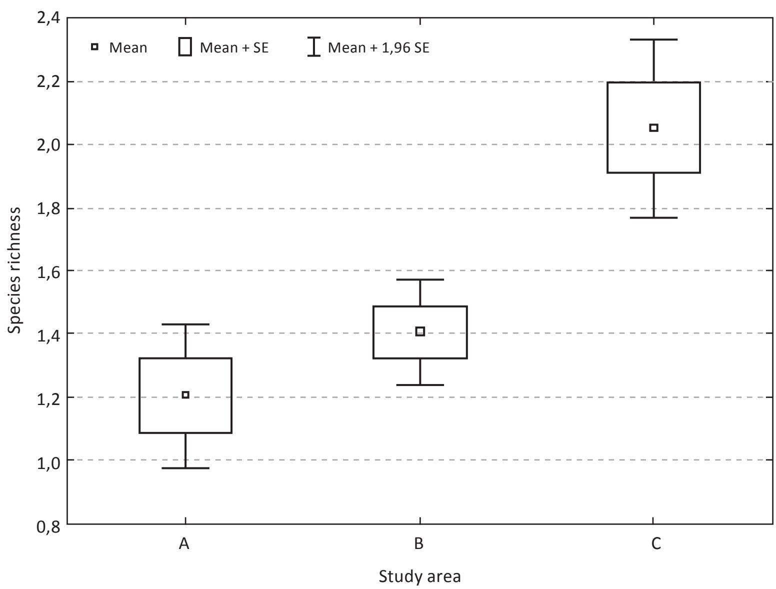

Figure 2. Means of numbers of species of Carabidae populating three urban forests (A, B, and C). Significance is indicated at p < 0,05

The Canonical Correspondence Analysis (CCA) revealed a positive correlation between the presence of deciduous trees and the first ordinance axis, describing 90% of the variability (tab. 3, fig. 3). A negative correlation with the first ordinance axis was demonstrated for anthropopressure. The second ordinance axis was correlated with lake distance and high habitat humidity. These two factors favoured a frequent occurrence of specific stenotopic Carabidae species, associated with very moist habitats. The presence of *Nebria brevicollis*, dominant in all the three tree communities, was most strongly correlated with the first ordinance axis and with one of the distinguished habitat traits, i.e. the presence of deciduous trees.

Table 3. Summary of the results of the canonical correspondence analysis for the studied carabid beetles assemblages

Axes	1	2	3	4	Total variance
Eigenvalues:	0.469	0.051	0.383	0.036	1.000
Species-environment correlations:	0.751	0.741	0.000	0.000	
Cumulative percentage variance					
of species data:	46.9	51.9	90.2	93.9	
of species-environment relation:	90.3	100.0	0.0	0.0	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.519

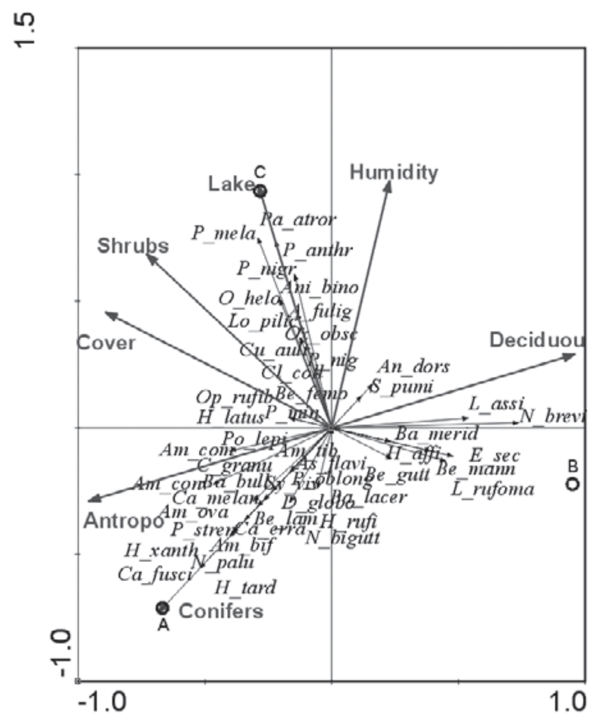

Figure 3. CCA ordinance diagram describing the relationship between species of Carabidae and the environmental variables humidity (Humidity), anthropopressure (Anthropo), soil cover (Cover), presence of deciduous trees (Decidouo), presence of coniferous trees (Cornifers), presence of shrubs (Shrubs) and distance to lake (Lake).

Discussion

In total, 49 species of Carabidae were captured in the examined tree communities, which corresponds to about 20% of all carabid species identified for north-eastern Poland (Aleksandrowicz *et al*. 2003). The number of species in the three parks was comparable to results reported by other authors (Żelazna & Błażejewicz-Zawadzińska 2006, Nietupski *et al*. 2008a,b, Kosewska *et al*. 2011, Kosewska *et al.* 2013). However, the number of carabid species detected in the present study was higher than that reported for urban areas in other countries (project Globenet), ranging from 13 (Japan) to 44 species (Bulgaria). The number of Carabidae caught in tree communities in Olsztyn is comparable to results reported from Denmark, Belgium and England (Magura *et al*. 2010). Magura *et al.* (2008) as well as Niemela & Kotze (2009) point out that the number and species richness of Carabidae dwelling in towns are increasing from the town centre towards suburban areas. In contrast, our results showed the highest number of species in habitats under strongest anthropogenic pressure, and most individuals were observed in the oldest tree assemblage, relatively unexposed to human activity.

A high number of species with each a low number of specimens results in a higher value of the Shannon-Weaver diversity index and the associated Pielou index of evenness. These indices do not always indicate a high ecological value of the examined area. A higher species diversity is not essential for rare or untypical species to appear (Buterfield *et al*. 1995). In our study, the Simpson species richness index (D) achieved the highest value (0.57) in the tree community at site B. Therefore, this result should be concomittant with the highest number of captured individuals in all the investigated parks. However, this index pays less attention to the occurrence of rare species, i.e. with low frequency, but indicates the presence of common species. In tree community B, a high frequency of one species, i.e. *Nebria brevicollis*, was observed (74% of all carabid beetles). According to Czechowski (1981), habitats strongly exposed to negative factors are often noticed to experience disorders in the species dominance system. Therefore, it can be concluded that the above mentioned community is somewhat unbalanced, possibly because of the very high homogeneity of that habitat.

The activity of carabid beetles depends on a number of factors. Sadler *et al*. (2006) who investigated communities of Carabidae inhabiting urban and suburban areas found that one of the environmental variables that significantly affected these assemblages was human activity but not soil moisture. Our analysis of correspondence (CCA) enabled to evaluate the effects of the analyzed environmental factors on the presence of carabid deetles, revealing the significance of both anthropopressure and humidity.

Conclusions

1. Urban tree assemblages of various types are a source of diversity and species richness of beetles of the family Carabidae.
2. Plant composition, human pressure as well as habitat humidity are factors most strongly influencing the structure of Carabidae communities.

Bibliography

Aleksandrowicz O., Gawroński R., Browarski B., 2003: New species of carabid beetles (Coleoptera: Carabidae) from North-East Poland. Baltic J. Coleopterol. 3 (2): 153-156.

Angold P.G., Sadler J.P., Hill M.O., Pullin A., Rushton S., Austin K., E.Small, Wood B., Wadsworth R., Sanderson R., Thompson K., 2006: Biodiversity in urban habitat patches. Sci. Tot. Environ. 360: 196-204.

Butterfield J., Luff M.L., Baines M., Eyre M.D., 1995: Carabid beetle communities as indicators of conservation potential in upland forests. Forest Ecol. and Manag. 79: 63-77.

Czechowski W., 1981: Biegaczowate (Carabidae, Coleoptera). Fragm. Faun. 26 (12): 193-216.

Czechowski W., 1982: Wpływ urbanizacji środowiska na dynamikę sezonową biegaczowatych (Carabidae, Coleoptera). Przegląd zoologiczny, Instytut Zoologii PAN, Warszawa 26 (1): 69-74.

Elek Z., Lovei G.L., 2007: Patterns in ground beetle (Coleoptera: Carabidae) assemblages along an urbanisation gradient in Denmark. Acta Ecologica 32: 104-111.

Hůrka K., 1996: Carabidae of the Czech and Slovak Republics. Kabournek – Zlin.

Kosewska A., Nietupski M., Damszel M., Ciepielewska D., 2011: Park miejski i cmentarze jako siedliska występowania naziemnych biegaczowatych (Col., Carabidae). Zesz. Probl. Post. Nauk Roln. 562: 95-105.

Kosewska A., Nietupski M., Damszel M., 2013: Role of urban forests as a source of diversity of carabids (Coleoptera: Carabidae) in urbanised areas. Baltic J. Coleopterol. 13 (1): 27-39.

Magura T., Lövei G., Tóthmérész B., 2008: Time-consistent rearrangement of carabid beetle assemblages by an urbanisation gradient in Hungary. Acta Oecologica 34: 233-243.

Magura T., Lövei G.L., Tóthmérész B., 2010: Does urbanization decrease diversity in ground beetle (Carabidae) assemblages? Global Ecol. and Biogeography 19 (1): 16-26.

Mc Geoch M., 1998: The selection, testing and application of terrestrial insects as bioindicators. Biol. Rev. 73: 181-201.

Mc Intyre N.E., Rango J., Fagan W.F., Faeth S.H., 2001: Ground arthropod community structure in a heterogeneous urban environmen. Landscape and Urban Planning 52: 257-274.

Niemela J., 1999: Ecology and urban planning. Biodivers. Conserv. 8: 119-131.

Niemela J., Kotze J., Ashworth A., Brandmayr P., Desender K., New T., Penev L., Samways M., Spencer J., 2000: The search for common anthropogenic impacts on biodiversity: a global network. J. Insect Conserv. 4: 3-9.

Niemela J., Kotze D.J., 2009: Carabid beetle assemblages along urban to rural gradients: A review. Landscape and Urban Planning 92: 65-71.

Nietupski M., Ciepielewska D., Kosewska A., 2008a: Assemblages of epigeic Carabidae (Col.) in a peat-bog nature reserve situated in an urban area. Pol. J. Natur. Sc. 23 (3): 611-623.

Nietupski M., Kosewska A., Ciepielewska D., Sądej W., 2008b: Zgrupowania Carabidae leśnego rezerwatu torfowiskowego zlokalizowanego w obrębie aglomeracji miejskiej. Sylwan 11: 16-25.

Rainio J., Niemela J., 2003: Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodivers. Conserv. 12: 487-506.

Sadler J.P., Small E.C., Fiszpan H., Telfer M.G., Niemela J., 2006: Investigating environmental variation and landscape characteristics of an urban-rural gradient using woodland carabid assemblages. J. Biogeogr. 33: 1126-1138.

Skłodowski J., 2002: System kolonizacji zrębów leśnych przez biegaczowate oraz możliwości jego doskonalenia. Rozprawy naukowe i monografie. SGGW, Warszawa.

Szyszko J., 2002: Carabids as an efficient indicator of the quality and functioning of forest ecosystems useful in forestry management. How to protect or what we know about Carabid Beetles. Warsaw Agricultural University Press: 301-318.

Ter Braak C.J.F., Milauer P.S., 1998: CANOCO Reference Manual and User's Guide to Canoco for Windows. Microcomputer Power, Ithaca, USA.

Żelazna E., Błażejewicz-Zawadzińska M., 2006: Zróżnicowanie gatunkowe biegaczowatych (Coleoptera: Carabidae) terenów parkowych Bydgoszczy oraz wybranych kompleksów leśnych i zadrzewień śródpolnych obszaru kujawsko-pomorskiego. Wiad. entomol. 25: 129-140.